Науки о Земле
Earth sciences

UDC 551.7+550.8 http://doi.org/10.21440/2307-2091-2023-2-7-17

Lithostratigraphy and geological evolution of Triassic rocks in the Palmyride Basin in Syria

Nosheen MOHAMMAD[1,2*]
Nadiya KHAMADA[1,2**]
Abd Azeez TAWIL[2***]
Alaa ABDULLAH[3****]
Abdul Rahim AL-TARBOUSH[2,4*****]

[1]Kazan (Volga region) Federal University, Kazan, Republic of Tatarstan, Russia
[2]Damascus University, Damascus, Syria
[3]Aleppo University, Aleppo, Syria
[4]Ebla Petroleum Company, Damascus, Syria

Abstract

The purpose of the research. This research aims to study the lithostratigraphy and geologic evolution of the Kurrachine Dolomite Formation in the middle Triassic along the Palmyrian Belt Zone in Syria. Studying this formation in its northern and southern parts has shown that it consists of two lithostratigraphic members, where each of them includes a series of lithological units. The petrographical study of the components of these units shows that they are composed of four distinguished components: dolomitic limestones, clayey limestones, clay and anhydrites, pure or mixed and deposited in repeated harmonic layers, gathered mostly in neutral sedimentary sequences.

The relevance of the research. This scientific research can provide information about the sedimentary evolution and stratigraphic succession of the region and its historical development. In addition, it can provide insight into the relationships between different sedimentary layers, and mineral resources available in the basin and their potential for exploitation. This research can also lead to a better understanding of the ancient environment in the region.

Research methodology. Data was collected from a range of sources, including geological maps and cross-sections, drill core log data from nine gas wells in the field, field observations, and published research. The study area was divided into different lithostratigraphic units, and the geology of each was studied in detail. Attention was paid to the lithology, hydrocarbon content, structural features and other features of each unit. The data collected was then used to construct a geological history of the region, including its tectonic, sedimentary, and paleogeographic evolution. This information was then used to make inferences about the regional stratigraphic framework, as well as to make predictions about future geological evolution.

Results and conclusions. This article focuses on the lithostratigraphy, as well as the geological evolution, of Triassic rocks, specifically the Kurrachine Dolomite Formation in the Northeastern Palmyride Basin of Syria. Laboratory studies were conducted to explore the lithology and sedimentary facies of the formation. Results show that the Kurrachine Dolomite Formation is dominated by deposits of a limited lithological nature. It is limited to calcareous, limestone, dolomitic limestones, dolomite, shale, and clay rocks, with limited intrusions of anhydrite in the upper part. The sedimentary environment of the formation is interpreted as shallow-marine. All analysis reveals that the Kurrachine Dolomite Formation is mainly composed of Middle Triassic deposits. This indicates a change in the sedimentation dynamics in the Palmyride Basin during the Middle Triassic. The results of the study provide a better understanding of the geological evolution of the Palmyride Basin in Syria.

***Keywords*:** Lithostratigraphy, Kurrachine Dolomite, Palmyrian, Dolomitic limestones, Syria.

✉nosheen.g.mohammad@gmail.com
https://orcid.org/0000-0002-3893-041X
**nadia.m.hamada@gmail.com
https://orcid.org/0000-0003-3269-6842
***abdazeez1101@gmail.com
https://orcid.org/0009-0006-9484-1493
****alaa663108@gmail.com
https://orcid.org/0000-0002-0477-2062
*****AbdTar0997@gmail.com
https://orcid.org/0009-0000-0916-3269

Introduction

Syria primarily belongs to the Arabian plate's margin, northern section (Arabian Syria), in the vicinity of the active zone of collision with Eurasia from the Precambrian to the present. Syria holds a portion of the Levantine Plate (Levantine Syria) (fig. 1). The plate divides the faulting system of the Dead Sea (Levantine) [1]. Individualization of the Arabia plate impacted the Levant during the Neogene, resulting in the formation of the Dead Sea (or Levant) Fault. In the middle of the Cenozoic period, the Arab plate splits from the African plate [1, 2]. The plate's orientation and position, impacted by tectonic movements, have altered multiple times, as evidenced by climate oscillation, depositional conditions and a tectonic-structural setting with features of both passive and active borders (fig. 1, *a*) [2, 3]. The distribution of tectonic provinces and structural boundaries on the plate's northern border is mostly determined by Cenozoic tectonic events. The thrust belt and Zagros fold, which trend northwesterly, is now the most prominent barrier (west Iran and eastern Iraq) [4]. It accommodates Arabia's convergence with Eurasia through broad thrusting, folding, and crustal shortening. The west limit is defined by the sinistral Dead Sea fault system, which accommodates the differing northward migration of the Arabian and African plates caused by the opening of the Red Sea [1].

Syria has four major tectonic zones (fig. 1, *b*): the Palmyride fold belt zone, the Sinjar-Abd El Aziz uplift zone, the Euphrates Depression, and the Dead Sea Fault System. Only one – the Dead Sea Fault System – is a non-hydrocarbon producing zone [5]. Cumulatively, the best producer is the Mesopotamian foredeep, a regional-scale flexural depression that extends from Iraq into NE Syria.

The study region is in the middle Palmyrides. The Palmyrides are a great indicator of an intracontinental transpressive mountain belt and the most important formation in central Syria [1, 6, 7]. From the Anti-Lebanon Mountains and the Dead Sea fault system, the Palmyrides strike N45E into the Euphrates Graben in the northeast, where they drop and vanish. The Palmyride mountain chain is 400 kilometers long and 100 kilometers broad, with a maximum elevation of around 1400 meters (fig. 1, *b*). The mountain belt is bounded by two structural highs, Alepo to the northwest and Rutbah to the southeast.

The study area is located north of the city of Palmyra, 70 km away from it in the Twenan field. It is one of the important structures with high hydrocarbon potential, as it contains two important formations (Kurrachine Dolomite and Butma). The field is an oil and gas producing complex with an area of 33 (km^2) belonging to the North Palmyra unit. Where The Twenan (TW) oil and gas field located to the southwest of the oil and gas-producing Akram structure, and it is located east of the gas-producing AlKhashabiya structure. The field is an elongated fold that takes a direction (northeast, southwest) interrupted by several main faults that take the direction of installation and divide it into blocks in addition to faults perpendicular to the direction of the main faults, which increases the complexity of the structure.

During the Neogene, the Red Sea opened, the Dead Sea Fault System activated, the Eastern Mediterranean opened, convergence and obduction occurred in southern Turkey and Iran, and the Arabian and Eurasian Plates collided. The sediments from the Plamyrides depocenter were raised and inverted into their present condition. The region is still in the compressional phase. The procedure should be separated into at least three stages [8, 9].

The first uplift was detected at the end of the Cretaceous (–65 Ma), the second uplift and local onlap occurred during the mid-Eocene, and the final and most important uplifting phase began approximately 20 Ma ago (Early Miocene) and is currently active [7]. This most recent uplifting was essential because it most likely constitutes a watershed moment in the

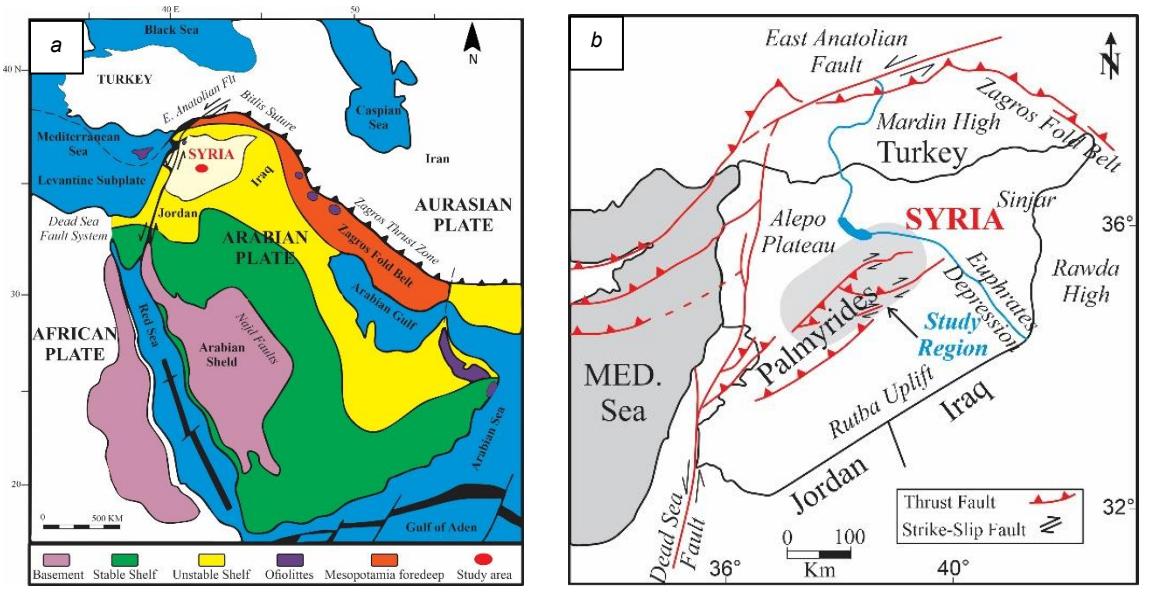

Figure 1. Map of the study region and nearby tectonic features: *a* – Regional tectonic setting of the northern Arabian Platform (modified from [1]); *b* – Syria's primary structural components (modified from [4])

Рисунок 1. Карта района исследования и близлежащих тектонических особенностей: *а* – региональная тектоническая обстановка северной части Аравийской платформы (с изменениями из [1]); *б* – основные структурные компоненты Сирии (с изменениями из [4])

history of Syrian terrains. Folding, reverse faulting, and tiny block rotation along multiple strike slip faults were all part of the inversion process.

Palmyrides split into northern and southern Palmyrides because of the differing tectonic types, which are separated by the regional Jihar fault and the Al Daww depression [10]. The north Palmyrides are composed of large, reasonably symmetric anticlines with reversal faults that descend into the belt's core along its southern and northern sides. The Salamieh and Homs depressions are on the northern side, while the Jihar fault is on the southern side. In the middle are two structural blocks, Bishri and Bilas. The Bilas block is a strike-slip duplex structure that is limited on the south by the Jihar dextral strike-slip fault and on the north by the Bishri dextral strike-slip fault. Jihar fault is one of the most important strike-slip fault systems in Palmyrides, dividing the SW and NE Palmyrides [11]. The fault has been traced over 200 kilometers in an ENE direction, with an average of 1000 meters of elevation. Al Daww depression is a form of intramountain basin that constitutes a depocenter from the Miocene to the present. More than 5 000 m of Mesozoic and 6 000 m of Paleozoic deposits lie in the depression.

Research materials and methods

In this paper, lithostratigraphy has been used to analyze the geological evolution of a region. To do this, data were collected from a range of sources, including geological maps and cross-sections, drill core log data from 9 gas wells in the field, field observations, and published research. The study area was divided into different lithostratigraphic units, and the geology of each was studied in detail (fig. 2, *a*, *b*). Attention was paid to the lithology, hydrocarbon content, structural features, and other features of each unit. The data collected was then used to construct a geological history of the region, including its tectonic, sedimentary, and paleogeographic evolution. This information was then used to make inferences about the regional stratigraphic framework, as well as to make predictions about future geological evolution.

In this field, 23 wells were drilled, the most important in terms of oil (TW-1, TW-2, TW-3, TW-10, TW-11) (fig. 2, *b*) while the most important in terms of gas (TW-101, TW-104, TW-105). It turns out that this field constitutes an important oil and gas field. The TW-1 well was drilled in order to test and determine the oil potentials of the formations produced in the neighboring fields of different ages, such as the Marqada formation from the Carboniferous, Kurrachine Dolomite from the Middle Triassic and Haramon of the Jurassic.

Lithostratigraphic analysis is an important part of geological research, and it can be conducted through the use of much geological software. In this scientific research we have

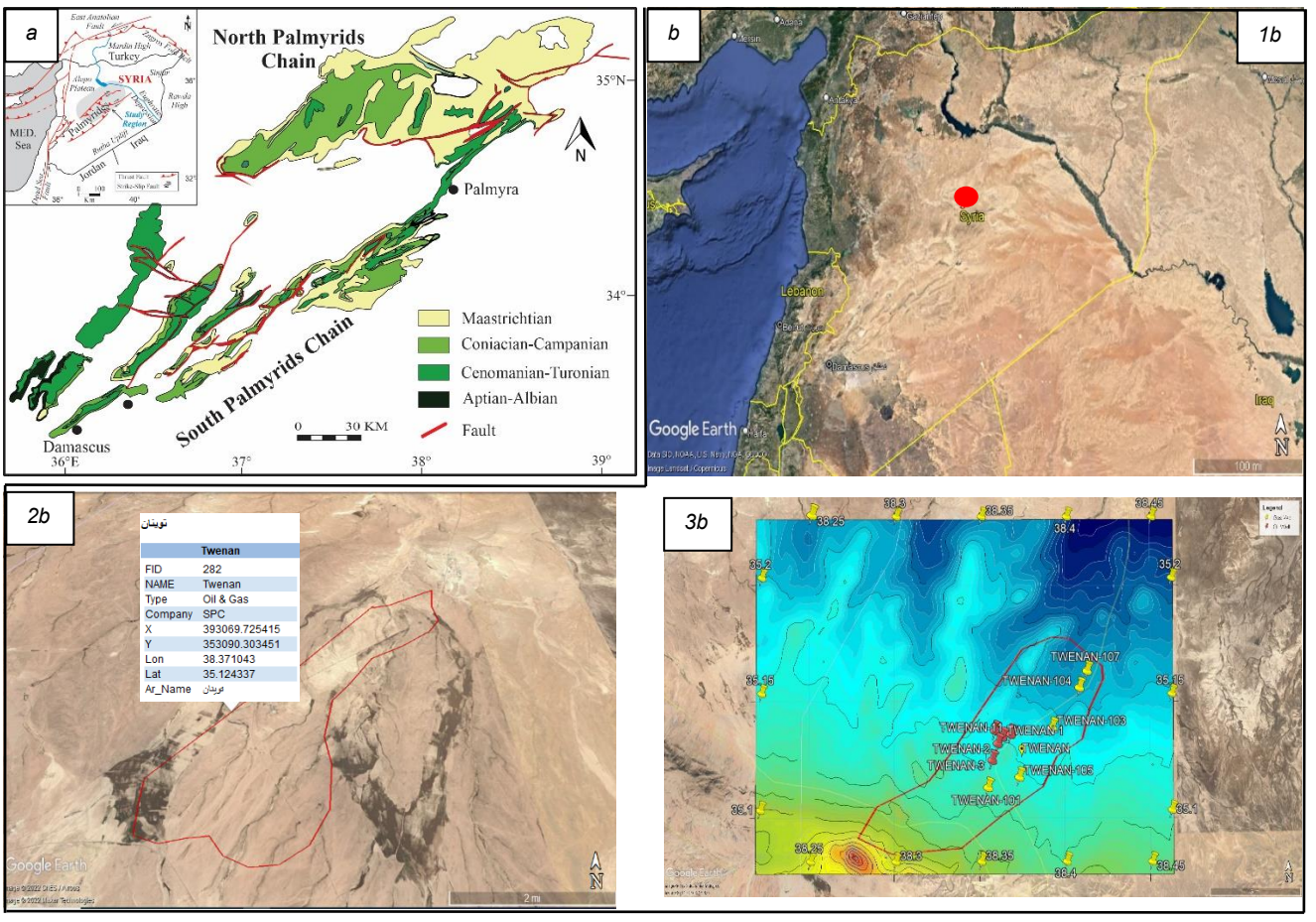

Figure 2. Location map of the study area: *a* – The Cretaceous outcrops of the Palm Rides (modified from [12]); *b* – Google Earth map of the study area showing: *1b* – the study area with the red circle, *2b* – boundary of the field, *3b* – oil and gas wells in the field

Рисунок 2. Карта расположения района исследований: *а* – меловые обнажения Палм-Райдс (с изменениями из [12]); *б* – карта Google Earth изучаемой территории, на которой показаны: *1б* – изучаемая территория с красным кружком, *2б* – граница месторождения, *3б* – нефтяные и газовые скважины месторождения

used many software programs like interactive petrophysics IP, Petrel and Google Earth. This type of software products allows us to easily identify and map out lithostratigraphic units and can also analyze the geologic relationships between different types of rocks and sedimentary strata. By using these software packages, we can quickly and accurately identify and analyze the different layers of a rock formation to better understand its history.

Geophysical well logs data was acquired from various oil and gas wells across the region of interest. The logs data included gamma ray, resistivity, sonic, density, and neutron logs (fig. 4, *a*). The lithostratigraphic analysis was performed using Gamma Ray log curves and well log correlation. Gamma Ray log curves were used to identify the major lithological units. Cross-well correlation was used to identify the lithostratigraphic units in the neighboring wells. The boundaries of different lithostratigraphic units were determined by comparing the gamma ray logs and well log curves from the neighboring wells. The interpreted lithostratigraphic units were mapped and analyzed in order to understand the sedimentary architecture.

Results and discussion

The Kurrachine Dolomite Formation of the Palmyride Basin in Syria is an important area of investigation for geologists and other scientists because it is considered to be a key area of Triassic sedimentary rocks [13]. This formation is composed mostly of dolomite and limestone and is located in the Triassic rocks in the middle of the Palmyride Structure, a large fault system in the uppermost part of the Palmyride Basin (fig. 3). This formation is important because it provides insight into the depositional environment of the Triassic period.

This study of the Lithostratigraphy and geological evolution of Triassic rocks in the Palmyride Basin in Syria has revealed a complex sequence of events that took place during the Triassic period. The Kurrachine Dolomite Formation is a Triassic deposit made up of dolomite, limestone, shale and sandstone. It represents a shallow marine depositional environment that was likely deposited in the paleogeographic depression in the Palmyride Basin.

Petrographic analysis of the Kurrachine Dolomite Formation in the Palmyride Basin in Syria revealed that the dolomite is generally fine- to medium-grained and composed of a variety of minerals, including calcite, quartz, anhydrite and pyrite (fig. 4, 6). The dolomite has a wide range of porosity from 0 to 15%. The mean porosity is 4.1%. Petrographic analysis also showed that the dolomite contained abundant secondary porosity, which is mostly matrix-supported. Calcite is the dominant cementing mineral, with rare occurrences of anhydrite and pyrite. The dolomite has a wide range of permeability, with the highest values being observed in the zone of secondary porosity. The dolomite is generally less permeable than sandstone. Overall, the petrographic of the Kurrachine Dolomite Formation in the Palmyride Basin in Syria reveals that it is fine- to medium-grained and composed of a variety of minerals (fig. 4, *b*).

The stratigraphic sequences are characterized by sedimentary structures such as lamination, ripple marks, and load casts. These features suggest that the Kurrachine Dolomite Formation was deposited in a near-shore environment and then subjected to multiple episodes of tidal, storm, and/or wave action (fig. 4).

The Kurrachine Dolomite Formation in the Palmyride Basin in Syria has a depositional environment that is composed mostly of shallow marine carbonates, but also includes characteristic features of a fluvial system. The majority of the formation is composed of limestone, dolomite, and sandstone beds, with minor shale siltstone (fig. 5). These sediments were deposited in shallow water environments with fluctuations in water depth, likely due to episodes of increased sedimentation and tectonically induced subsidence. These fluctuations would influence the sediment composition, with deeper water areas having a higher proportion of fine-grained sediment.

The presence of biogenic limestone and dolomite in the Kurrachine Dolomite Formation indicates periods of anoxic bottom water, which is indicative of a shallow, low-energy marine depositional environment. The presence of sandstone beds in the formation suggests that there were episodes of fluvial activity, which provided the source of the coarser-grained sed-

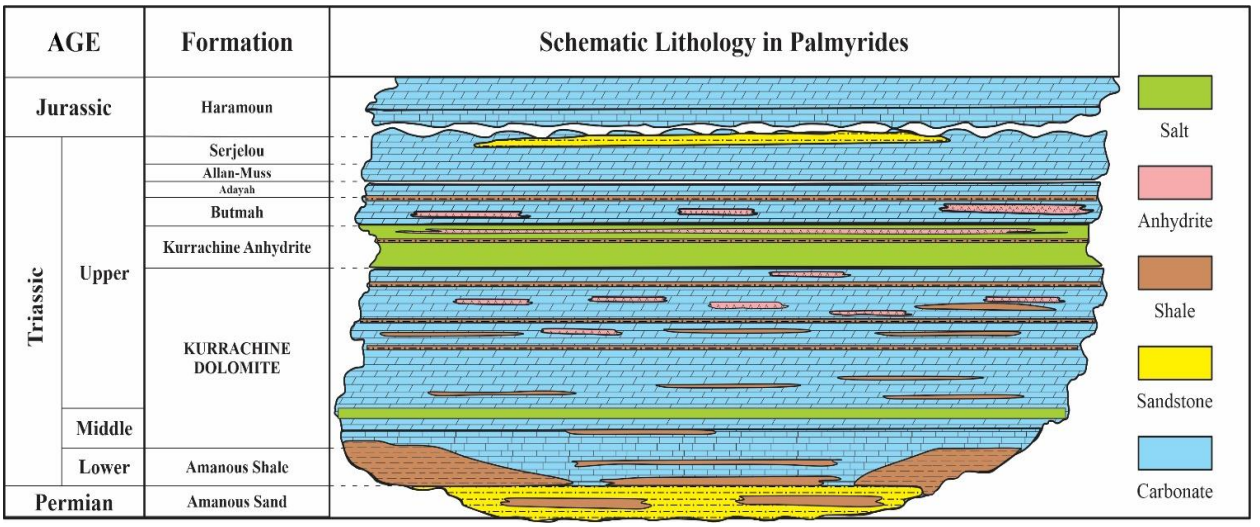

Figure 3. Lithostratigraphic units and Schematic Lithology in Palmyrides (modified from [14])
Рисунок 3. Литостратиграфические единицы и схематическая литология в Пальмиридах (с изменениями из [14])

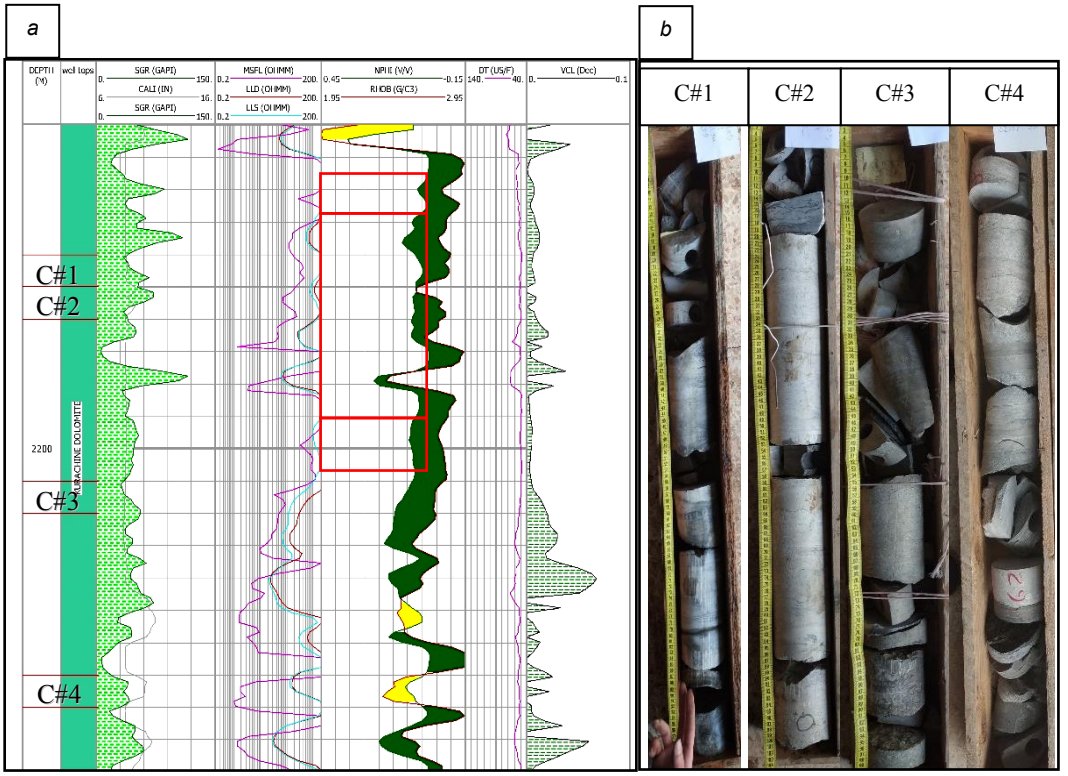

Figure 4. Logging evaluation with Core view in Kurrachine dolomite formation in the TW-105: *a* – well logs (gamma ray, resistivity, porosity, Sonic and their interpretation in the volume of clay) by interactive petrophysics IP software; *b* – The photos of cores in different lithology of Kurrachine dolomite formation in the well TW-105: C#1 the interval from 2194 m to 2195 m, C#2 the interval from 2195 m to 2196 m, C#3 the interval from 2201 m to 2202 m, C#4 the interval from 2207 m to 2208 m. Where these intervals are described as containing clay layers at the bottom, followed by dolomitic facies interspersed with thin layers of calcareous rocks in its upper part, and then ending with an anhydrite facies

Рисунок 4. Оценка каротажа с просмотром керна в доломитовой формации Куррачин в скважине TW-105: *а* – каротажные диаграммы (гамма-каротажи, электросопротивление, пористость, акустика и их интерпретация в объеме глины) с помощью интерактивного программного обеспечения IP для изучения горных пород; *б* – фотографии керна в разной литологии доломитовой формации Куррачин в скважине TW-105: C#1 интервал с 2194 м до 2195 м, C#2 интервал с 2195 м до 2196 м, C#3 интервал от 2201 м до 2202 м, C#4 интервал от 2207 м до 2208 м. Эти интервалы описываются как содержащие глинистые прослои в нижней части, за которыми следуют доломитовые фации с вкраплениями маломощных прослоев известняковых пород в верхней части, заканчивающиеся ангидритовой фацией

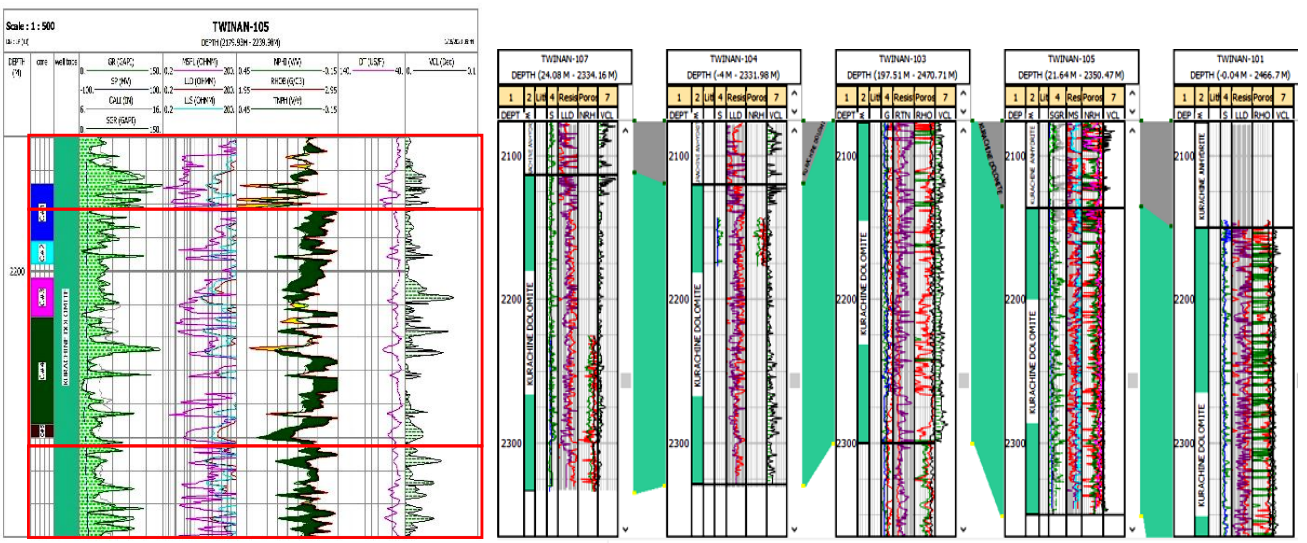

Figure 5. Logging characterization of the Kurrachine dolomite formation in the TW-105 well and correlation with other wells by interactive petrophysics IP software

Рисунок 5. Каротажная характеристика доломитовой формации Куррачин в скважине TW-105 и корреляция с другими скважинами с помощью интерактивного программного обеспечения IP для изучения горных пород

iment. The presence of fossils indicates that this environment was also home to a diverse marine fauna. Overall, the depositional environment of the Kurrachine Dolomite Formation in the Palmyride Basin was composed of shallow marine carbonates, with intermittent.

The detailed petrographical study of the Kurrachine Dolomite formation in the various structures of the study area, based on the microscopic and electron microscopic description of the fragments and rock core, and the interpretation of the associated well geophysical records, and with the help of previous descriptions carried out by the Syrian Oil Company or other foreign companies (fig. 5, 6), led to the following inferences: On the one hand, the formation consists of three lithostratigraphic members that are distinct by their facies, fossil content, and responses to borehole geophysical records. On the other hand, the formation is dominated by deposits of a limited lithological nature. It is limited to calcareous, limestone, dolomitic limestones, dolomite, shale and clay rocks, with limited intrusions of anhydrite in the upper part.

The sediments of the formation are distributed in the form of alternations or repeated successions consisting of decimeter to metric layers and sometimes decameter layers applied horizontally or semi-horizontally. This distribution does not reflect clear gradual developments on the well records. Some of the sediments in some sub-units tend to move from clay or clay-calcareous rocks to dolomitic calcareous rocks. Dolomite is rich in anhydrite, reflecting negative regression sequences. This rule may sometimes be reversed to turn those sequences into positive transgressions (fig. 5).

Clay materials are clastic in origin and are found in two shale patterns in the form of decimetric continuity between calcareous layers or normal in the form of transitional layers between calcareous and calcareous clay rocks. It is also sometimes found scattered in limestone or dolomitic rocks. Calcareous rocks are soft micrite rocks (of the type mudstone or weakstone) and may sometimes be biomicrite, but they are devoid of inorganic granular components.

In the formation Dolomitic rocks are (dolomicrite – dolomicrosparite) rocks with crystals of small or sometimes medium dimensions; It results from the recrystallization of the primary micrite material in an early or contemporary form of sedimentation, or it is related to the dolomite epigenesis.

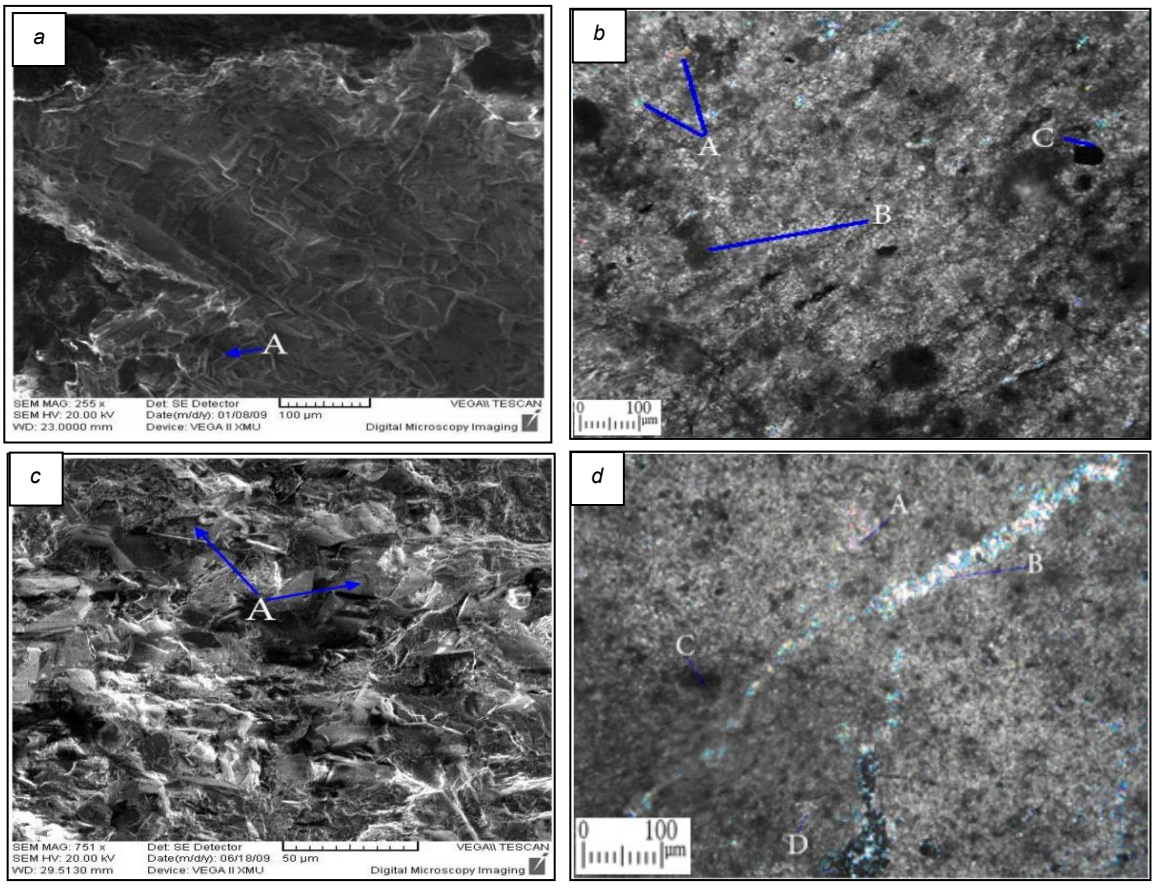

Figure 6. Some microfacies of limestone deposits in the Kurrachine dolomite formation: *a* – (TW-105) 2208-2207.5 m: Euhedral dolomite exhibits well-developed crystal faces; *b* – (TW-105) 2212-2211 m: Mixed clays with anhydrite and pyrite in millimeter dimensions. A: Anhydrite; B: Clay; C: Pyrite; *c* – (TW-105) 2218-2217 m: Micrite with crystals of dolomite. A: Dolomite; *d* – (TW-105) 2218-2217 m: Partially and partially cracked dolomitic micrite. A: Anhydrite; B: Crack filled with anhydrite; C: Clay; D: Dolomite

Рисунок 6. Некоторые микрофации отложений известняков доломитовой формации Куррачин: *а* – (TW-105) 2208-2207,5 м: идиоморфный доломит с хорошо развитыми гранями кристаллов; *б* – (TW-105) 2212-2211 м: глины, смешанные с ангидритом и пиритом в миллиметровых размерах. А: ангидрит; Б: глина; С: пирит; *в* – (TW-105) 2218-2217 м: микрит с кристаллами доломита. А: доломит; *г* – (TW-105) 2218-2217 м: частично растрескавшийся доломитовый микрит. А: ангидрит; В: трещина заполнена ангидритом; С: глина; Д: доломит

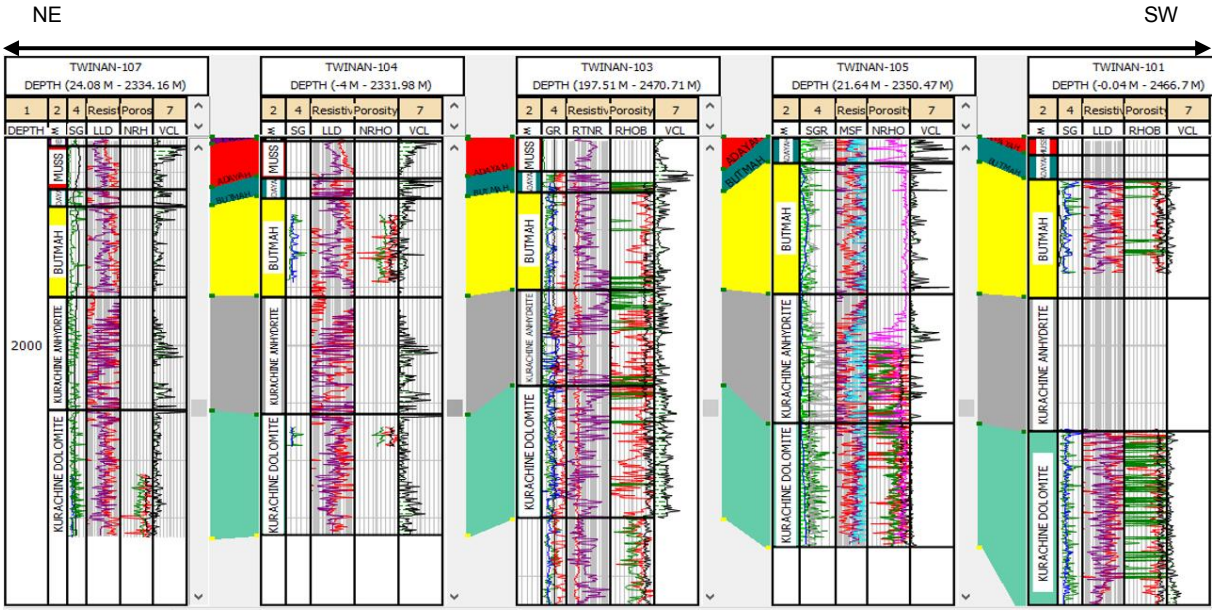

Figure 7. NE-SW correlation of well logs showing the identified formation (Kurrachine dolomite) across the five gas wells. The results of correlation were obtained from the analysis of well log data by interactive petrophysics IP software
Рисунок 7. Корреляция СВ-ЮЗ каротажных диаграмм, показывающая идентифицированную формацию (куррачинский доломит) по пяти газовым скважинам. Результаты корреляции были получены из анализа каротажных данных с помощью интерактивного программного обеспечения IP для изучения горных пород

Anhydrite sediments occupy an important place in the formation; They appear as large, clear crystals that grow in the form of thin interferences or clumps within the dolomitic rocks. The sediments, especially the calcareous ones, contain a significant proportion of crystallized pyrite (fig. 5, 6).

The correlation process aims to compare the Kurrachine Dolomite formation at all the points that were studied in the northern Palmyra fold range, and to understand the facies changes experienced by the members, units and subunits of the formation along the study area in terms of thickness and different facies. As a result, a comparison was made between a group of reference wells for the compositions that were previously studied, starting from the southwest towards the northeast (fig. 7), and they are: (TW-101, TW-105, TW-103, TW-104, TW-109) by well logs record: gamma ray, resistivity, sonic, density, and neutron logs.

The comparison process between the wells of the studied area led to the following (fig. 7): first, the formation kept its divisions between all wells into three members (lower, middle and upper). The members also kept their divisions in units and subunits that can be compared from one well to another. Second, the thickness of the members and units of this formation differed from one well to another, with a slight variation in their facies.

The Palmyrides Basin in Syria is a region that has experienced an incredibly complex geological evolution. It has been shaped by both tectonic and erosional processes, leading to a highly diverse region of sedimentary rocks and structures. The basin is considered to be a rift basin, likely formed during the Late Cretaceous period, resulting in a variety of sedimentary deposits, including shale, limestone and sandstone [15] (fig. 8).

In the Paleozoic, the Palmyrides Basin was a passive margin, with sedimentation taking place mainly in an intracratonic basin. During the Mesozoic, it started to transition into an active margin, associated with the opening of the Neo-Tethys Ocean. This transition was accompanied by the southwestward drift of the Arabian Plate, leading to the creation of the Palmyrides Basin (fig. 8, *a*).

In the Cenozoic, the basin experienced uplift and erosion, leading to the formation of the Palmyrides Mountains. This uplift and erosion also led to the deposition of deep-water sediments in the basin, forming the distinctive Palmyrides Formation.

The Palmyrides Basin in Syria is an area of geological interest due to its complex history of formation and evolution. The Palmyrides Basin is part of the Syrian Desert, which is located in the Fertile Crescent, an area approximately encircling the eastern Mediterranean Sea. The Palmyrides Basin is a structural and sedimentary basin that is made up of thick-bedded limestone and marl formations, creating an undulating topography.

The Palmyrides Basin is thought to have formed in response to the collision of the Arabian and African plates, which created the Levant-Syria-Palestine-Arabian Arc. This collision caused the Palmyrides Basin to be uplifted and folded, resulting in the formation of rugged mountains and hills. The basin also experienced a period of tectonic activity, which caused further upliftment and resulted in an even more rugged landscape (fig. 8, *b*).

The Palmyrides Basin has experienced multiple phases of sedimentary deposition throughout its evolution. During the Miocene, a period of regional tectonic upliftment, shallow marine sediments were deposited in the basin. This resulted in the formation of siliciclastic sandstones, conglomerates and limestone deposits. Over time, these deposits were buried beneath further sedimentary deposits, such as the marl deposits which are now visible in the Palmyrides Basin.

Today, the Palmyrides Basin is a unique area of geological diversity, where the effects of millions of years of tectonic and

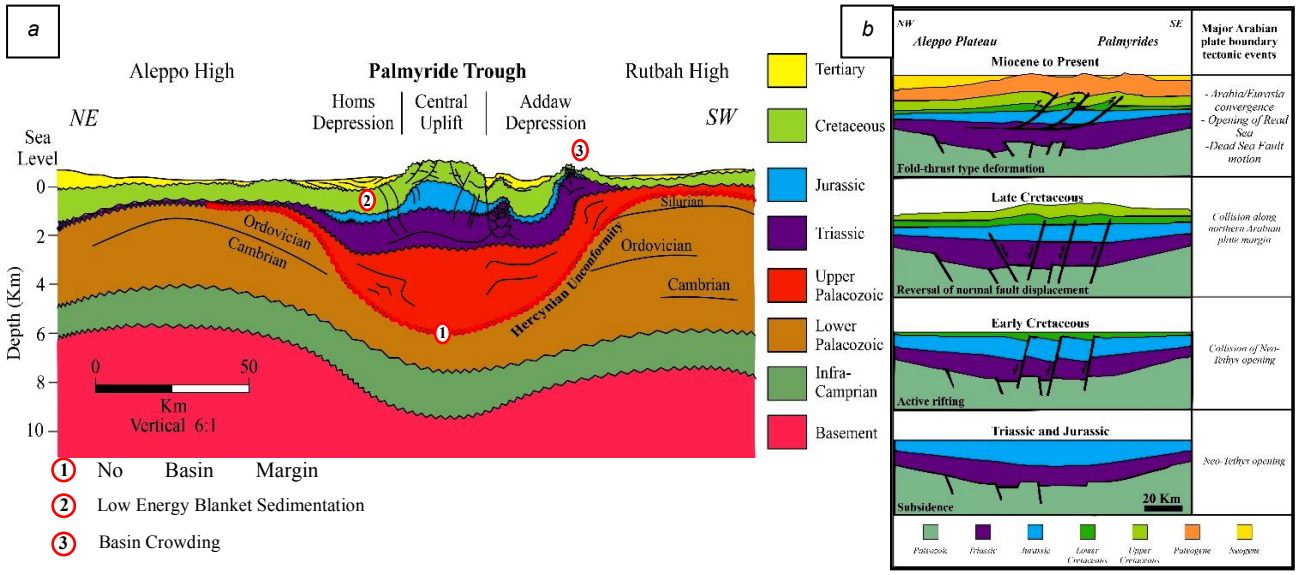

Figure 8. Schematic Palmyra cross section: *a* – Cross section of the Palmyride Trough (modified from [16]); *b* – Schematic NW-SE cross sections illustrating the development of the intraplate Palmyride fold belt, from bottom to top; with a related major Arabian plate boundary tectonic event (modified from [7])

Риснок 8. Схематический разрез Пальмиры: *а* – разрез Пальмиридского прогиба (с изменениями из [16]); *б* – схематические разрезы с северо-запада на юго-восток, иллюстрирующие развитие внутриплитного складчатого пояса Пальмирид; снизу вверх, с соответствующим крупным тектоническим событием на границе Аравийской плиты (изменено из [7])

erosional processes can be seen. It is a region of great geological importance, providing scientists with insight into the evolution of a rift basin.

Conclusions

The northeastern part of Palmeride is one of the important structures with high hydrocarbon potential, as it contains two important Triassic formations (Kurrachine Dolomite and Butmah). The formation comprises three lithostratigraphic members that are distinct by their facies, sediments, and responses to borehole geophysical records.

Many possible carbonate reservoir intervals can be found in the Triassic deposits. In the Palmyrides, the fractured carbonates of the Middle-Late Triassic Kurrachine Dolomite Formation represent major gas and oil reserves.

The Kurrachine Dolomite Formation is one of the important formations in the middle Triassic that make up the stratigraphic column in the northern Palmyra fold range. The formation is bordered by two possible hiatuses that separate the two formations that host it: the overlying Kurrachine anhydrite formation and the underlying Amanus shell formation.

REFERENCES

1. Brew G., Barazangi M., Al-Maleh A. K., Sawaf T. 2001, Tectonic and geologic evolution of Syria. *GeoArabia*, vol. 6, no. 4, pp. 573–616. https://doi.org/10.2113/geoarabia0604573a
2. Homberg C., Bachmann M. 2010, Evolution of the Levant margin and western Arabia Platform since the Mesozoic: introduction. *Geological Society, London, Special Publications*, vol. 341, pp. 1–8. https://doi.org/10.1144/SP341.1
3. Metwalli M. H., Philip G., Moussly M. M. 1974, Petroleum-bearing formations in northeastern Syria and northern Iraq. *AAPG Bulletin*, vol. 58, no. 9, pp. 1781–1796. https://dx.doi.org/10.1306/83D919AC-16C7-11D7-8645000102C1865D
4. Litak R. K., Barazangi M., Beauchamp W., Seber D., Brew G., Sawaf T., Al-Youssef W., 1997. Mesozoic-Cenozoic evolution of the intraplate Euphrates fault system, Syria: implications for regional tectonics. *Journal of the geological society*, vol. 154, no. 4, pp. 653–666. https://doi.org/10.1144/gsjgs.154.4.0653
5. Sawaf T., Al-Saad D., Gebran A., Barazangi M., Best J. A. Chaimov T. A., 1993. Stratigraphy and structure of eastern Syria across the Euphrates depression. *Tectonophysics*, vol. 220, issues 1-4, pp. 267–281. https://doi.org/10.1016/0040-1951(93)90235-C
6. Ponikarov V. P. 1966, The Geological Map of Syria Scale 1 : 200 000, Sheet I-37-XV (Tudmor): Explanatory notes. Damaskus: Syrian Arab Republic, Ministry of Industry.
7. Chaimov T. A., Barazangi M., Al-Saad D., Sawaf T., Gebran A. 1992, Mesozoic and Cenozoic deformation inferred from seismic stratigraphy in the southwestern intracontinental Palmyride fold-thrust belt, Syria. *Geological Society of America Bulletin*, vol. 104, no. 6, pp. 704–715. https://dx.doi.org/10.1130/0016-7606(1992)104%3C0704:MACDIF%3E2.3.CO;2
8. Barrier E., Machhour L., Blaizot M. 2014, Petroleum systems of Syria. *AAPG Memoir*, vol. 106, pp. 335–378. https://doi.org/10.1036/13431862M1063612
9. Brew G., Best J., Barazangi M., Sawaf T. 2003, Tectonic evolution of the NE Palmyride mountain belt, Syria: the Bishri crustal block. *Journal of the Geological Society*, vol. 160, no. 5, pp. 677–685. https://doi.org/10.1144/0016-764902-161
10. McBride J. H., Barazangi M., Best J., Al-Saad D., Sawaf T., Al-Otri M., Gebran A. 1990, Seismic reflection structure of intracratonic Palmyride fold-thrust belt and surrounding Arabian platform, Syria. *AAPG Bulletin*, vol. 74, no. 3, pp. 238–259.
11. Caron C., Mouty M. 2007, Key elements to clarify the 110 million year hiatus in the Mesozoic of eastern Syria. *GeoArabia*, vol. 12, no. 2, pp. 15–36. https://doi.org/10.2113/geoarabia120215
12. Ghanem H., Mouty M., Kuss J. 2012, Biostratigraphy and carbon-isotope stratigraphy of the uppermost Aptian to Upper Cenomanian strata of the South Palmyrides, Syria. *GeoArabia*, vol. 17, no. 2, pp.155–184. https://doi.org/10.2113/geoarabia1702155
13. Hips K., Árgyelán G. B. 2007, Controls on diagenesis of the Triassic Kurrachine Dolomite, Syria. *GeoArabia*, vol. 12, no. 2, pp. 41–64. https://doi.org/10.2113/geoarabia120241

14. Lučić D., Ivković Z., Foršek G., Takač D., Bubnić J., Koch G. 2010, Depositional sequences and palynology of Triassic carbonate-evaporite platform deposits in the Palmyrides, Syria. *Geological Society, London, Special Publications*, vol. 329, no. 1, pp. 43–63. https://doi.org/10.1144/SP329.3
15. Vulama I. 2011, Source Rock Potential and Petroleum Systems of the Triassic and Paleozoic Successions of the Hayan Block, Central Syrian Palmyrides. *International Journal of Geophysics and Geochemistry*, vol. 2, no. 3, pp. 80–91.
16. Wood B. G. M. 2015, Rethinking post-Hercynian basin development: Eastern Mediterranean region. *GeoArabia*, vol. 20, no. 3, pp. 175–224. https://doi.org/10.2113/geoarabia2003175

The article was received on April 01, 2023

УДК 551.7+550.8 http://doi.org/10.21440/2307-2091-2023-2-7-17

Литостратиграфия и геологическая эволюция триасовых пород бассейна Пальмирид в Сирии

Ношин МОХАММАД[1,2*]
Надия ХАМАДА[1,2**]
Абд Азиз ТАВИЛЬ[2***]
Алаа АБДУЛЛА[3****]
Абдул Рахим АЛЬ-ТАРБУШ[2,4*****]

[1]Казанский (Приволжский) федеральный университет, Республика Татарстан, Россия
[2]Дамасский университет, Дамаск, Сирия
[3]Университет Алеппо, Алеппо, Сирия
[4]Нефтяная компания «Эбла», Дамаск, Сирия

Аннотация

Цель исследования. Исследование направлено на изучение литостратиграфии и геологической эволюции доломитовой формации Куррачин в среднем триасе вдоль зоны Пальмирского пояса в Сирии. Изучение этой формации в ее северной и южной частях показало, что она состоит из двух литостратиграфических пачек, каждая из которых включает ряд литологических единиц. Петрографическое изучение компонентов толщ показывает, что они состоят из четырех выделенных компонентов: доломитовых известняков, глинистых известняков, глины и ангидритов, чистых или смешанных, отложенных в повторяющихся гармонических слоях и собранных в основном в нейтральных осадочных толщах.

Актуальность исследования. Данное научное исследование предоставляет информацию об эволюции осадочных пород и стратиграфической последовательности региона и его историческом развитии. Кроме того, оно может дать представление о взаимосвязях между различными осадочными слоями и минеральными ресурсами, доступными в бассейне, и их потенциале для разработки. Исследование также дает возможность лучше понять особенности древней окружающей среды в регионе.

Методы исследования. Данные были собраны из ряда источников, включая геологические карты и разрезы, данные каротажа керна из девяти газовых скважин на месторождении, полевые наблюдения и опубликованные исследования. Район исследования был разделен на различные литостратиграфические единицы и геология каждой из них была подробно изучена. Внимание уделялось литологии, углеводородному составу, особенностям строения и другим особенностям каждой пачки. Собранные данные затем использовались для построения геологической истории региона, включая его тектоническую, осадочную и палеогеографическую эволюцию. Затем эта информация использовалась для выводов о региональной стратиграфической структуре, а также для прогнозов будущей геологической эволюции.

Результаты и выводы. Статья посвящена литостратиграфии, а также геологической эволюции триасовых пород, в частности доломитовой формации Куррачин в северо-восточном бассейне Пальмирид в Сирии. Были проведены лабораторные исследования по изучению литологии и осадочных фаций формации. Результаты показывают, что в доломитовой формации Куррачин преобладают месторождения ограниченной литологической природы. Здесь представлены известняки, доломитовые известняки, доломиты, сланцы и глинистые породы с ограниченными интрузиями ангидрита в верхней части. Осадочная среда формации интерпретируется как мелководно-морская. Весь анализ показывает, что доломитовая формация Куррачин в основном состоит из отложений среднего триаса. Это указывает на изменение динамики осадконакопления в бассейне Пальмирид в течение среднего триаса. Результаты исследования позволяют лучше понять геологическую эволюцию бассейна Пальмирид в Сирии.

Ключевые слова: литостратиграфия, куррачинские доломиты, пальмирские известняки, доломитовые известняки, Сирия.

✉nosheen.g.mohammad@gmail.com
https://orcid.org/0000-0002-3893-041X
**nadia.m.hamada@gmail.com
https://orcid.org/0000-0003-3269-6842
***abdazeez1101@gmail.com
https://orcid.org/0009-0006-9484-1493
****alaa663108@gmail.com
https://orcid.org/0000-0002-0477-2062
*****AbdTar0997@gmail.com
https://orcid.org/0009-0000-0916-3269

ЛИТЕРАТУРА

1. Brew G., Barazangi M., Al-Maleh A. K., Sawaf T. Tectonic and geologic evolution of Syria. // GeoArabia. 2001. Vol. 6. No. 4. P. 573–616. https://doi.org/10.2113/geoarabia0604573a
2. Homberg C., Bachmann M. Evolution of the Levant margin and western Arabia Platform since the Mesozoic: introduction. // Geological Society, London, Special Publications. 2010. Vol. 341. P. 1–8. https://doi.org/10.1144/SP341.1
3. Metwalli M. H., Philip G., Moussly M. M. Petroleum-bearing formations in northeastern Syria and northern Iraq. // AAPG Bulletin. 1974. Vol. 58. No. 9. P. 1781–1796. https://dx.doi.org/10.1306/83D919AC-16C7-11D7-8645000102C1865D
4. Litak R. K., Barazangi M., Beauchamp W., Seber D., Brew G., Sawaf T., Al-Youssef W. Mesozoic-Cenozoic evolution of the intraplate Euphrates fault system, Syria: implications for regional tectonics. // Journal of the geological society. 1997. Vol. 154. No. 4. P. 653–666. https://doi.org/10.1144/gsjgs.154.4.0653
5. Sawaf T., Al-Saad D., Gebran A., Barazangi M., Best J. A. Chaimov T. A. Stratigraphy and structure of eastern Syria across the Euphrates depression. // Tectonophysics. 1993. Vol. 220, issues 1-4. P. 267–281. https://doi.org/10.1016/0040-1951(93)90235-C
6. Ponikarov V. P. The Geological Map of Syria Scale 1 : 200 000, Sheet I-37-XV (Tudmor): Explanatory notes. Damaskus: Syrian Arab Republic, Ministry of Industry, 1966.
7. Chaimov T. A., Barazangi M., Al-Saad D., Sawaf T., Gebran A. Mesozoic and Cenozoic deformation inferred from seismic stratigraphy in the southwestern intracontinental Palmyride fold-thrust belt, Syria. // Geological Society of America Bulletin. 1992. Vol. 104. No. 6. P. 704–715. https://dx.doi.org/10.1130/0016-7606(1992)104%3C0704:MACDIF%3E2.3.CO;2
8. Barrier E., Machhour L., Blaizot M. Petroleum systems of Syria. // AAPG Memoir. 2014. Vol. 106. P. 335–378. https://doi.org/10.1036/13431862M1063612
9. Brew G., Best J., Barazangi M., Sawaf T. Tectonic evolution of the NE Palmyride mountain belt, Syria: the Bishri crustal block. // Journal of the Geological Society. 2003. Vol. 160. No. 5. P. 677–685. https://doi.org/10.1144/0016-764902-161
10. McBride J. H., Barazangi M., Best J., Al-Saad D., Sawaf T., Al-Otri M., Gebran A. Seismic reflection structure of intracratonic Palmyride fold-thrust belt and surrounding Arabian platform, Syria. // AAPG Bulletin. 1990. Vol. 74. No. 3. P. 238–259.
11. Caron C., Mouty M. Key elements to clarify the 110 million year hiatus in the Mesozoic of eastern Syria. // GeoArabia. 2007. Vol. 12. No. 2. P. 15–36. https://doi.org/10.2113/geoarabia120215
12. Ghanem H., Mouty M., Kuss J. Biostratigraphy and carbon-isotope stratigraphy of the uppermost Aptian to Upper Cenomanian strata of the South Palmyrides, Syria. // GeoArabia. 2012. Vol. 17. No. 2. P. 155–184. https://doi.org/10.2113/geoarabia1702155
13. Hips K., Árgyelán G. B. Controls on diagenesis of the Triassic Kurrachine Dolomite, Syria. // GeoArabia. 2007. Vol. 12. No. 2. P. 41–64. https://doi.org/10.2113/geoarabia120241
14. Lučić D., Ivković Z., Foršek G., Takač D., Bubnić J., Koch G. Depositional sequences and palynology of Triassic carbo-nate-evaporite platform deposits in the Palmyrides, Syria. // Geological Society, London, Special Publications. 2010. Vol. 329. No. 1. P. 43–63. https://doi.org/10.1144/SP329.3
15. Vulama I. Source Rock Potential and Petroleum Systems of the Triassic and Paleozoic Successions of the Hayan Block, Central Syrian Palmyrides. // International Journal of Geophysics and Geochemistry. 2011. Vol. 2. No. 3. P. 80–91.
16. Wood B. G. M. Rethinking post-Hercynian basin development: Eastern Mediterranean region. // GeoArabia. 2015. Vol. 20. No. 3. P. 175–224. https://doi.org/10.2113/geoarabia2003175

Статья поступила в редакцию 01 апреля 2023 года